ACTIVITIES OF ULTRAFAST NANOSCIENCE GROUP @ ELI-ALPS

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SZÉCHENYI 2020
HUNGARIAN GOVERNMENT
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ELI-ALPS

attosecond

User facility for providing femto- and attosecond pulses in combination with various endstations to investigate electromagnetic processes in atoms, molecules and solid state systems

https://www.eli-alps.hu/en/

Ultrafast nanoscience group

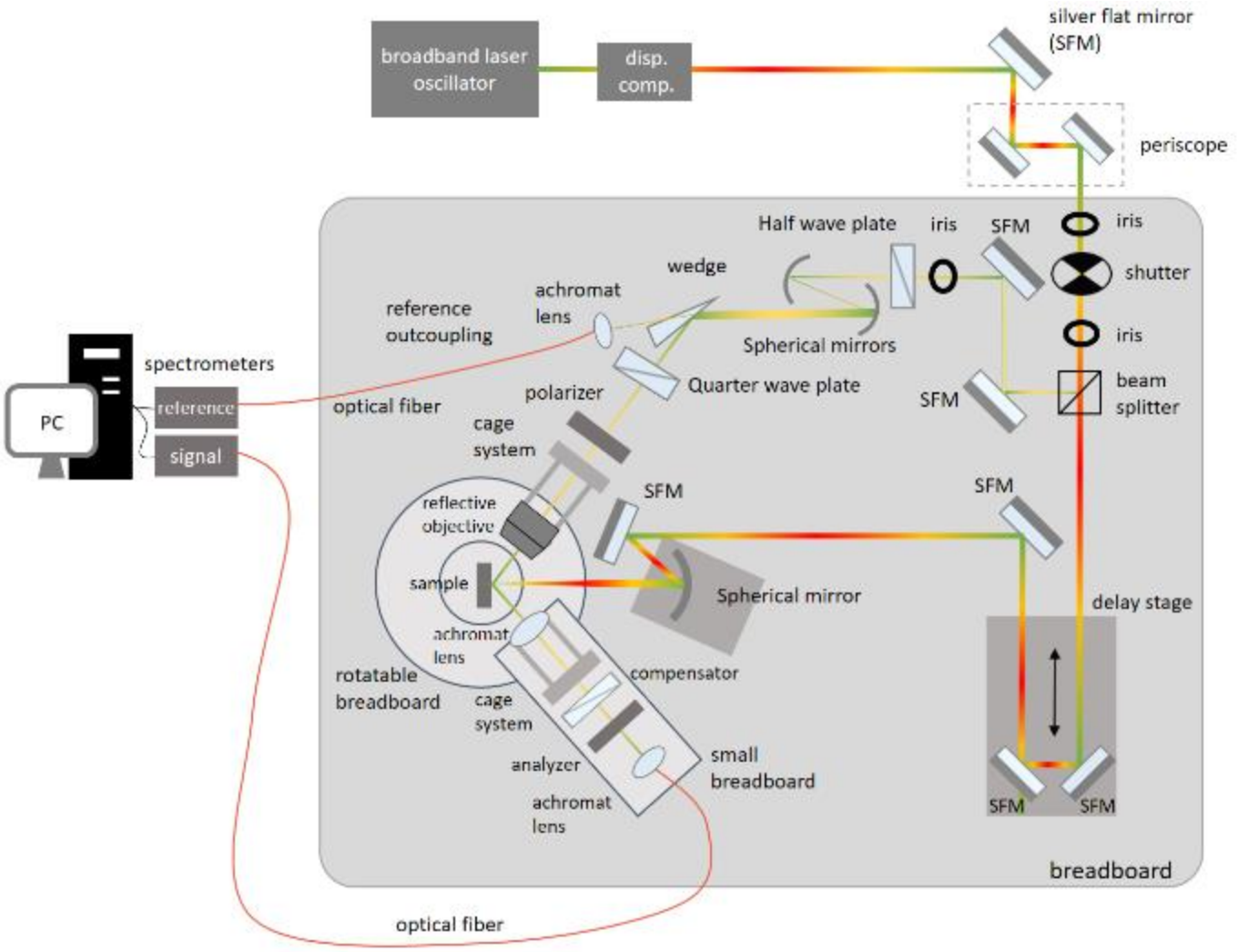
- performing experiments with various application-oriented nanosystems together with user groups
- providing nanofabrication support for facility users

Technologies used

- **Ultrafast Ellipsometry**
  - Time-resolved measurement of dielectric function upon ultrafast excitation
- **Electron beam lithography**
  - Complex procedure for nanustructure fabrication with high precision
- **Focused Ion Beam**
  - Direct milling of the samples with Ga ions
- **Scanning Near-Field Optical Microscopy**
  - Investigation of local interactions between ligth and solid surfaces

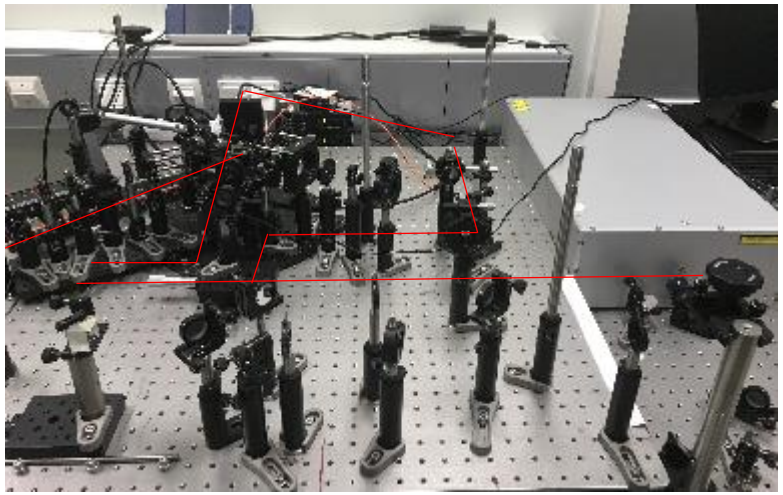
Time-resolved ellipsometry setup

Sketch of design



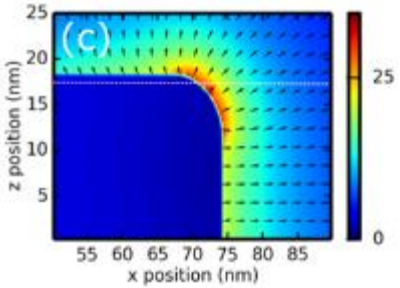
- We are developing a pseudo rotating compensator ellipsometer setup using the 10fs pulses of 80MHz Ti:S oscillator
- We have already calibrated the system in static mode
- We carried out the first time resolved reflectivity measurements on Al layer on glass

Present status

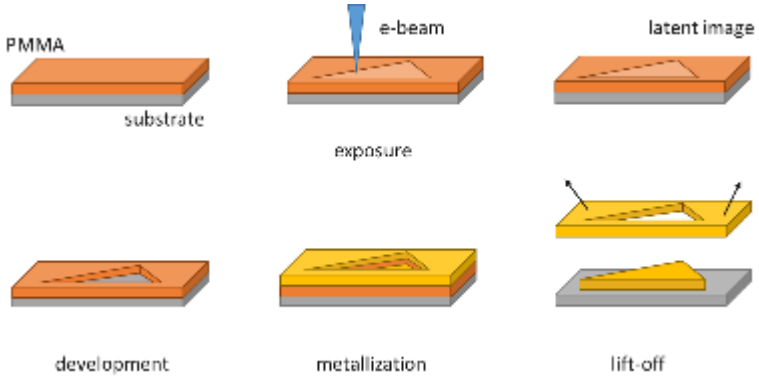


Electron beam lithography

- Design and fabrication of nanostructures:
  - helping in proper design with **Lumerical FDTD simulation** tool



  - Fabrication: **Raith eLINE Plus** system



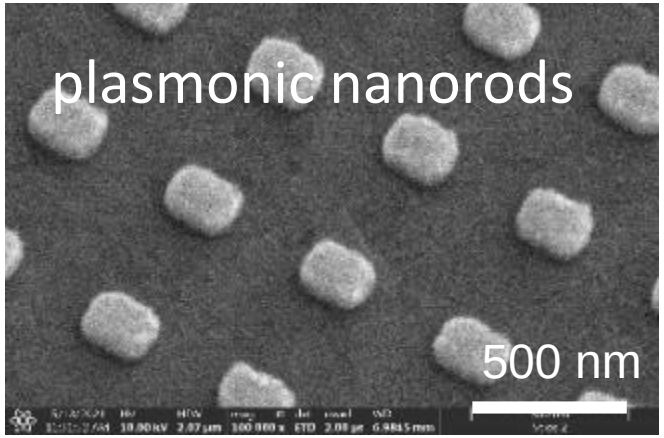
- Whole production line is available (spin coater, thermal evaporator)

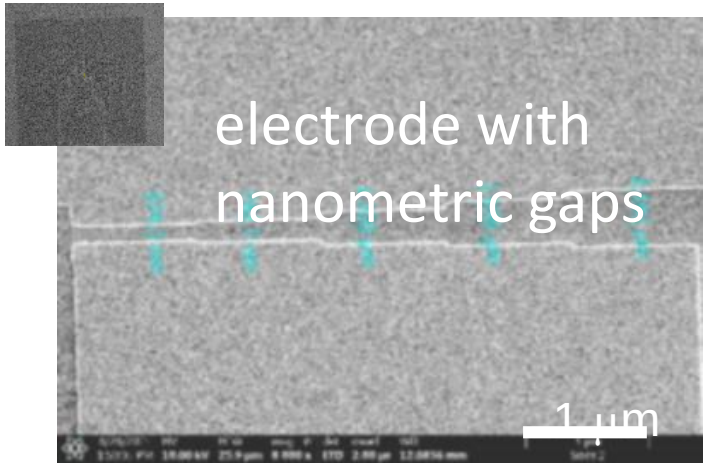
Electron beam lithography

Parameters	
Electron source	Schottky type thermal field emission
Electron energy available	100eV-30keV
Spotsize	2nm @20kV
Sample size:	•5mm - 10cm •100 x 100mm travel range laser interferometer-controlled stage
minimum grating periodicity	40nm
minimum feature size	8 nm
Detectors for SEM applications	•Everhart-Thornley secondary electron detector •in-lens secondary and backscattered electron detectors •X-ray spectrometer and energy dispersive microanalysis system

Routinely fabricated samples:

- Nano- and microstructures





- *Pápa et al., Applied Phys. Lett. 2022, 120, 053103*
- *Lovász et al., Nano Lett. 2022, 22, 6, 2303*
- *Hanus et al., Optica, 2021, 8, 570*
- *Hanus et al., Nat. Comm. 2023, 14, 5068*

Focused Ion Beam Device

Scios Focused Ion Beam device

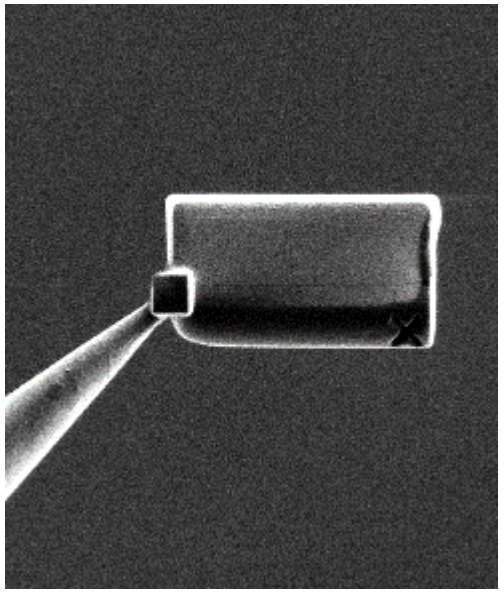
- direct milling of samples with Ga ions

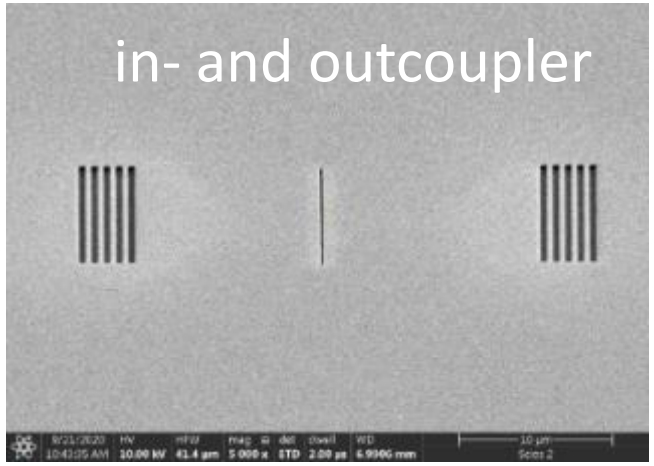
Parameters	
Electron source	Schottky type thermal field emission
Electron energy available	200eV-30keV
Ion source	Ga
Accelerating voltage for ion beam	500V and 30 kV
Ion current available	1.5 pA to 65 nA.
Sample size:	•5mm - 10cm
FIB accesories	•Pt gas-injection system •nano-manipulator
Detectors for electron microscopy applications	•Everhart-Thornley secondary electron detector •in-lens secondary and backscattered electron detectors •scanning TEM detector

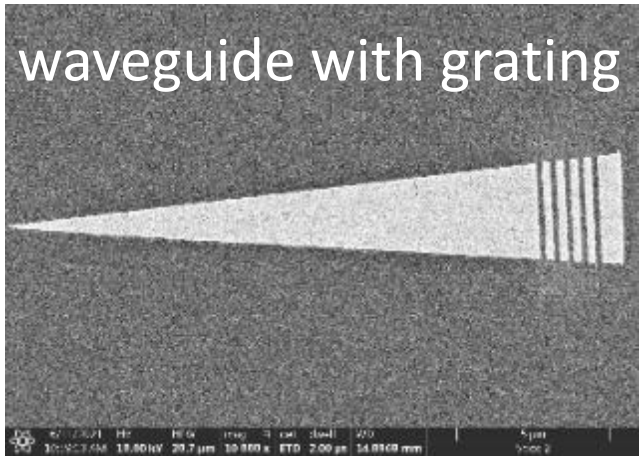
Focused Ion Beam Device

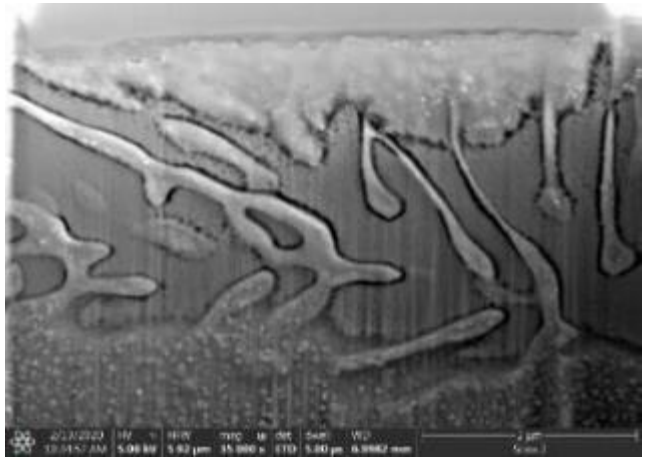
Routinly fabricated samples

- Gratings
- Cross sections for material analysis
- TEM lamellae









Lovasz et al., 2023, submitted
Komatsu et al., 2023, submitted

Scanning Near-Field Optical Microscopy

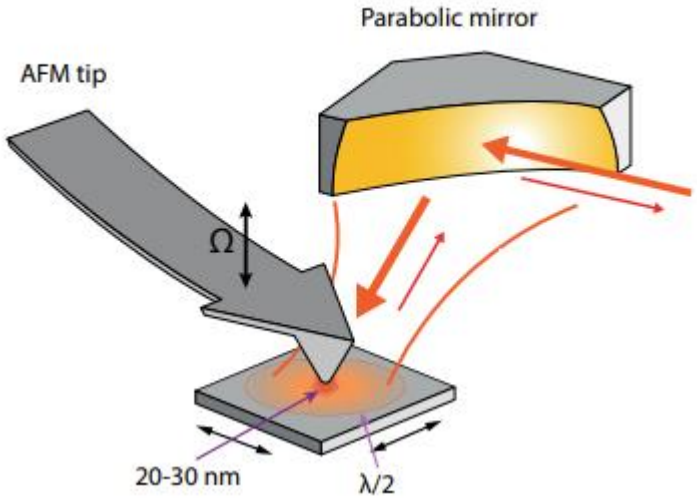


Figure from G. Nemeth PhD thesis

Neaspec VIS+ scanning near field optical microscope

Parameters	
Wavelengths	1550nm, 633nm, 533nm
CW-power	20mW, 10mW, 10mW
Measurement configuration	Reflection and transmission
Lateral scanning range	min. 90x90µm
Vertical scanning range	min. 2µm
Lateral scanning resolution	better than 0.5nm
Vertical scanning resolution	better than 0.2nm
Sample size:	min. 9 mm x 9 mm x 1 mm

- investigation of local interactions between electromagnetic radiation and solid surfaces
- direct information about the *amplitude* and *phase* of the scattered light

Scanning Near-Field Optical Microscopy

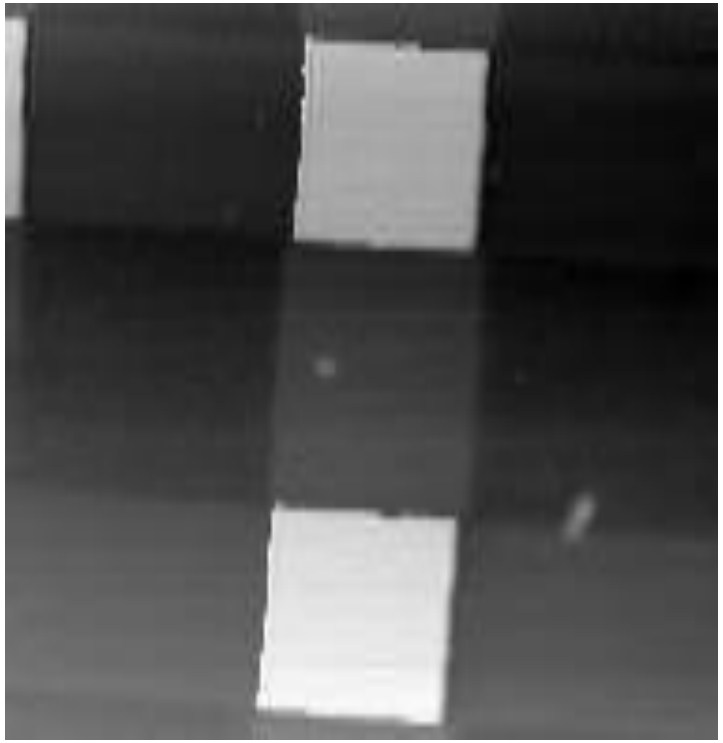
- available excitation geometries:
  - reflection: material composition ⇔ complex refractive index

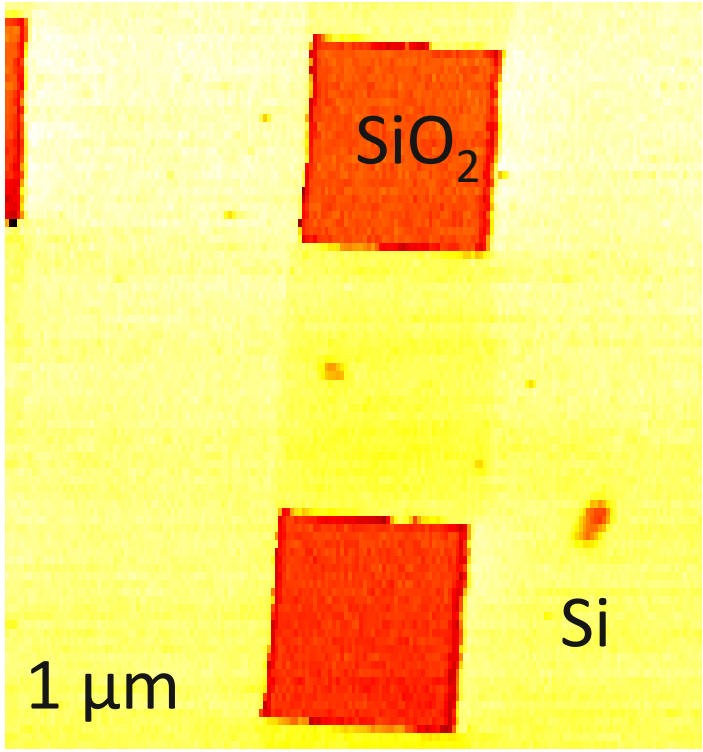
$$\beta = (\epsilon_s + 1)/(\epsilon_s + 1)$$

$$\alpha_{eff,z} = \frac{\alpha}{1 - \frac{\alpha\beta}{16\pi(R+h)^3}}$$

$$E_{sca} \propto (1 + cr_p)^2 \alpha_{eff} E_0$$

AFM image and optical amplitude map of a silicon surface containing SiO_2 islands



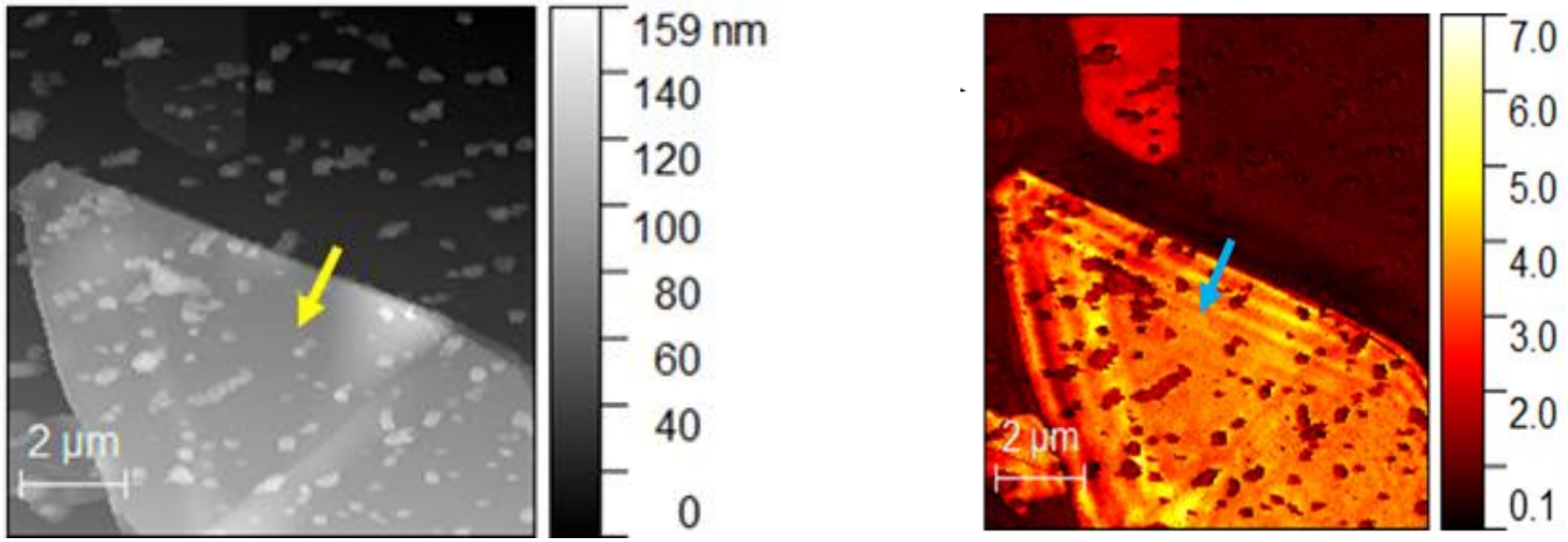


Scanning Near-Field Optical Microscopy

- available excitation geometries:
  - reflection:

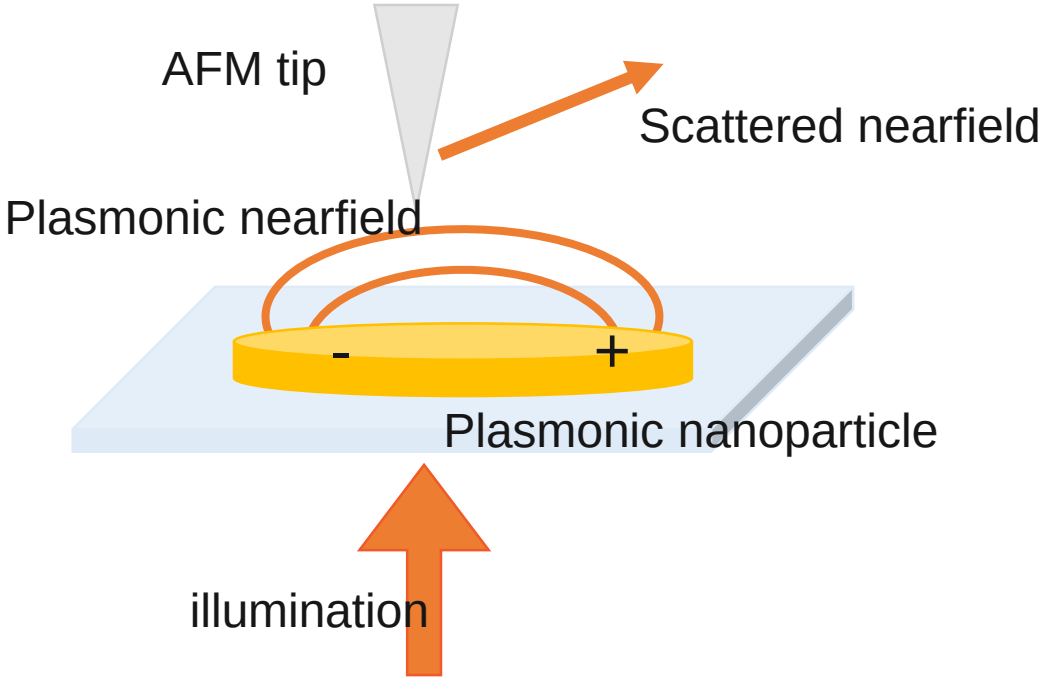
revealing exciton-polariton excitation

AFM and optical amplitude map of an exfoliated MoS_2 flake



Scanning Near-Field Optical Microscopy

- available excitation geometries:
  - transmission: revealing plasmonic modes



- Sample illuminated from the bottom
- Plasmon oscillations are excited.
- The tip interacts with the vertical component of the local field of the localised plasmon.

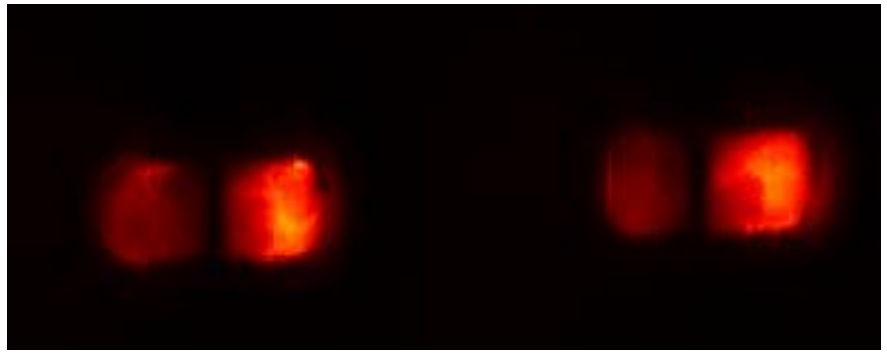
=> directly measure the amplitude and the phase distribution of plasmonic near field

Scanning Near-Field Optical Microscopy

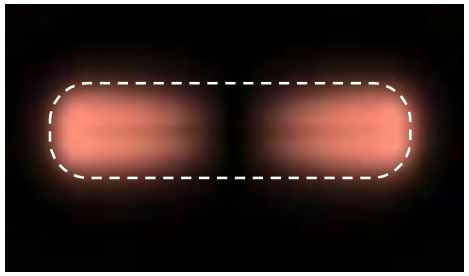
- available excitation geometries:
  - transmission: revealing plasmonic modes
  - sample: resonant plasmonic nanorod

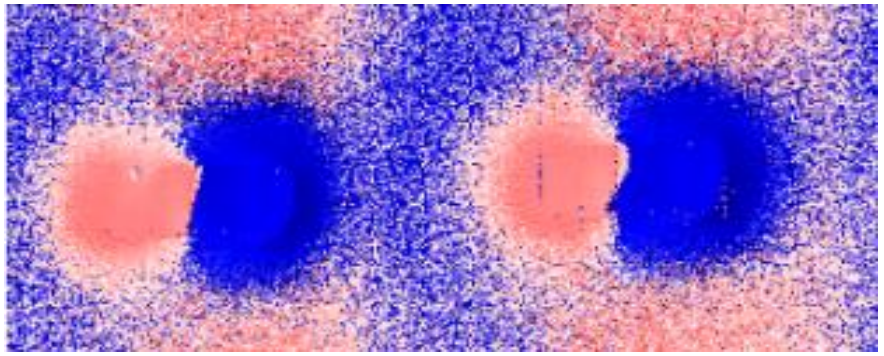
MEASUREMENT

SIMULATION



$|E_z|$





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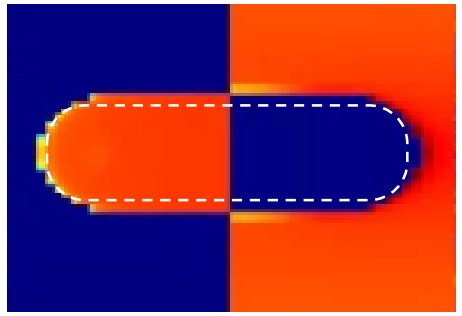

Summary

- Ultrafast ellipsometer setup being developed
- EBL, FIB – nanofabrication
- SNOM:
  - Reflection: changes in the local optical properties
  - Transmission: direct observation of plasmonic near fields

- All open for collaborations:

https://up.eli-laser.eu/call/3rd-eli-call-for-users-660963332

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THANK YOU FOR YOUR ATTENTION!

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